Decomposition of Scattering and Intrinsic Attenuation in Rock with Heterogeneous Multiphase Fluids

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RESEARCH OBJECTIVES

This project investigates scattering and intrinsic attenuation of seismic waves in rock with heterogeneous distributions of fluids and gas. This research represents a departure from past studies on seismic attenuation in that the focus here is not a detailed study of a specific attenuation mechanism, but rather an investigation of theoretical and laboratory methods for obtaining separate estimates of scattering and intrinsic attenuation in rock with heterogeneous pore fluid distributions.

The objectives of this project are threefold: (1) adapt and further refine methods for decomposing scattering and intrinsic attenuation in rock with heterogeneous multiphase fluids; (2) apply these methods to laboratory seismic measurements in porous rock with heterogeneous fluid distributions and compare these results with direct laboratory measurements; and (3) examine a new method for focusing seismic waves in heterogeneous media using time-reversal mirrors. These objectives are addressed in three tasks to be performed over a period of three years.

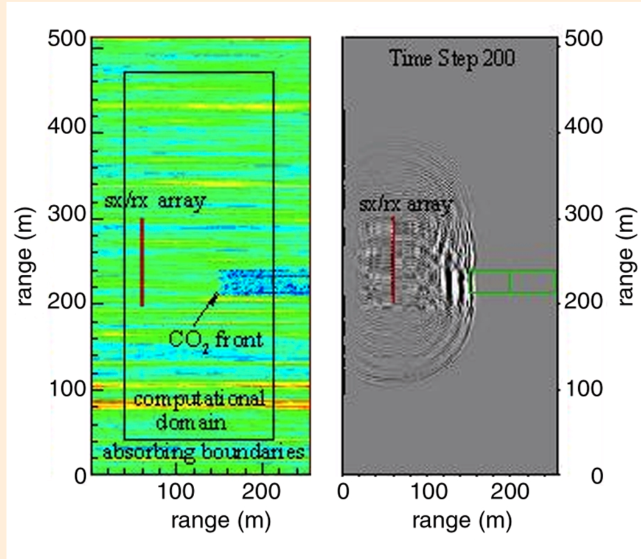

Figure 1. Selective focusing on a fluid front in a stratified elastic medium using the DORT algorithm applied to time-lapse differenced pressure data (26 source/receiver array, 100 Hz).

APPROACH

The first phase of this project has focused on the third objective: the adaptation of time-reversal focusing concepts to monitoring the movement of fluids in the subsurface using fixed arrays of sources and receivers that have the capability to selectively focus seismic waves on heterogeneities formed by the impedance contrast between fluids and gas. Unlike seismic imaging, focused arrays do not provide images of the subsurface, but rather attempt to enhance the scattered wavefield off the heterogeneity of interest while suppressing the scattering from surrounding heterogeneities. This is achieved by providing the appropriate phase shifts and amplitudes to the array of sources. The principal benefit of focusing is the potential to selectively illuminate heterogeneities in situ, thus providing information about the number and the strengths of the heterogeneities. In addition, the use of prefocused data in seismic imaging algorithms may potentially result in higher resolution images of heterogeneities in the subsurface.

ACCOMPLISHMENTS

Numerical studies of elastic wave focusing using a vertical array of sources and receivers were performed using 2-D finite difference simulations. The DORT (Decomposition of the Time Reversal Operator) algorithm (Prada and Fink, 1994) was applied to determine the source phasing parameters for selective focusing on a particular scatterer. The figure displays a time-lapse fluid-front monitoring example of the DORT method. Strong vertical multiple reflections from the layered stratigraphy near the source/receiver array result in poor focusing when applying DORT to the scattered wavefield. However, if time-lapse data is available, differencing the recorded wavefields obtained from surveys performed at two instances in time during the migration of the fluid front effectively filters out these vertical reverberations. Application of DORT to the differenced wavefield produce excellent focusing of the wavefield on the CO_2 front.

SIGNIFICANCE OF FINDINGS

While the potential of time-reversal focusing methods for reservoir monitoring is clear, a number of factors need to be addressed for the application to monitoring heterogeneous multiphase fluids. For example, the DORT method has been demonstrated to be robust for illuminating discrete scatterers embedded in fluids and tissues. Since geologic media typically contain scatterers of varying size, shape, density and aspect ratios, and, additionally, may be anisotropic and viscoelastic (time-reversal invariance breaks down in the presence of intrinsic attenuation, the focus of our research will be to adapt the time-reversal focusing method to heterogeneous, anisotropic, viscoelastic media.

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